USACERL INTERIM REPORT P-89/14
May 1989

US Army Corps
of Engineers
Construction Engineering
Research Laboratory

(2)



# May 1984 to September 1988 Summary of Fort Irwin, CA, Family Housing Comparison Test: Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units

by
Robert D. Neathammer



Congress directed the construction of 200 units of manufactured/factory-built housing at Fort Irwin, CA, in 1982 to see if this method of construction will cost less than conventional housing, yet still provide durable housing commensurate with contemporary housing standards.

Congress directed the Department of Defense (DOD) to conduct a fair and reliable study that will compare the operation and maintenance (O&M) costs of manufactured housing to those of conventional housing. DOD will report to Congressional committees on the conditions and parameters under which this test was conducted and the results of the test after the housing has been in use for 5 years.

To compare these two types of construction properly, DOD must reliably identify O&M costs and user satisfaction. Differences in O&M costs must be identified and the reasons for those differences determined.

This is the fifth of five interim reports on the progress of the study. USACERL will provide a yearly summary for each of FY84–FY88. A final report covering the first 5 years of O&M costs will be written at the end of FY89.

No conclusions or inferences should be made as to which type of construction has the lowest O&M costs until the final 5-year summary is complete.

# REPORT DOCUMENTATION PAGE

Form Approved
OMB No 0704 0188
Exp Date Jun 30 1986

1a REPORT SECURITY CLASSIFICATION
UNCLASSIFIED

1b RESTRICTIVE MARKINGS

2a SECURITY CLASSIFICATION AUTHORITY

2b DECLASSIFICATION / DOWNGRADING SCHEDULE

3 DISTRIBUTION / AVAILABILITY OF REPORT
Approved for public release; distribution is unlimited.

4 PERFORMING ORGANIZATION REPORT NUMBER(S)
USACERL IR P-89/14

5 MONITORING ORGANIZATION REPORT NUMBER(S)

6a NAME OF PERFORMING ORGANIZATION
U.S. Army Construction Engr Research Laboratory

6b OFFICE SYMBOL (If applicable)

7a NAME OF MONITORING ORGANIZATION

6c ADDRESS (City, State, and ZIP Code)
P.O. Box 4005
Champaign, IL 61824-4005

7b ADDRESS (City, State, and ZIP Code)

8a NAME OF FUNDING / SPONSORING ORGANIZATION
USAEHSC

8b OFFICE SYMBOL (If applicable)
CEHSC-HM

9 PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER
Intra Army Orders from Fort Irwin and HQFORSCOM; FHAA022-83, (cont'd)

8c ADDRESS (City, State, and ZIP Code)
Fort Belvoir, VA 22060-5580

10 SOURCE OF FUNDING NUMBERS

| PROGRAM ELEMENT NO. | PROJECT NO | TASK NO | WORK UNIT ACCESSION NO |
|---|---|---|---|
| | | | |

11 TITLE (Include Security Classification)
May 1984 to September 1988 Summary of Fort Irwin, CA, Family Housing Comparison Test: Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units (U)

12 PERSONAL AUTHOR(S)
Neathammer, Robert D.

| 13a TYPE OF REPORT | 13b TIME COVERED | 14 DATE OF REPORT (Year, Month, Day) | 15 PAGE COUNT |
|---|---|---|---|
| Interim | FROM _____ TO _____ | 1989, May | 29 |

16 SUPPLEMENTARY NOTATION
Copies are available from the National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

| 17 COSATI CODES | | |
|---|---|---|
| FIELD | GROUP | SUB-GROUP |
| 15 | 05 | |
| | | |

18 SUBJECT TERMS (Continue on reverse if necessary and identify by block number)
Fort Irwin, CA
Housing projects
Operation & maintenance
Cost analysis
Prefabricated buildings

19 ABSTRACT (Continue on reverse if necessary and identify by block number)

Congress directed the construction of 200 units of manufactured/factory-built housing at Fort Irwin, CA, in 1982 to see if this method of construction will cost less than conventional housing, yet still provide durable housing commensurate with contemporary housing standards.

Congress directed the Department of Defense (DOD) to conduct a fair and reliable study that will compare the operation and maintenance (O&M) costs of manufactured housing to those of conventional housing. DOD will report to Congressional committees on the conditions and parameters under which this test was conducted and the results of the test after the housing has been in use for 5 years.

(Cont'd)

20 DISTRIBUTION / AVAILABILITY OF ABSTRACT
☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT ☐ DTIC USERS

21 ABSTRACT SECURITY CLASSIFICATION
UNCLASSIFIED

22a NAME OF RESPONSIBLE INDIVIDUAL
Gloria J. Wienke

22b TELEPHONE (Include Area Code)
(217)352-6511 (x353)

22c OFFICE SYMBOL
CECER-IMT

DD FORM 1473, 84 MAR 83 APR edition may be used until exhausted
All other editions are obsolete

BLOCK 9. (Cont'd)

dated August, 1983; R039-84, dated May 1984; S040-85, dated January 1985; T016-86, dated November 1986; CERL-87, dated December 1987; CERL-88, dated June 1988.

BLOCK 19. (Cont'd)

To compare these two types of construction properly, DOD must reliably identify O&M costs and user satisfaction. Differences in O&M costs must be identified and the reasons for those differences determined.

This is the fifth of five interim reports on the progress of the study. USACERL will provide a yearly summary for each of FY84-FY88. A final report covering the first 5 years of O&M costs will be written at the end of FY89.

No conclusions or inferences should be made as to which type of construction has the lowest O&M costs until the final 5-year summary is complete.

## FOREWORD

This research was conducted for the U.S. Army Engineering and Housing Support Center (USAEHSC), under the following Intra Army Orders (IAOs) from Fort Irwin and Headquarters, U.S. Army Forces Command: FHAA022-83, dated August 1983; R039-84, dated May 1984; S040-85,dated January 1985; T016-86, dated November 1986; CERL-87, dated December 1987, and CERL-88, dated June 1988. The USAEHSC Technical Monitor was Mr. Alex Houtzager, CEHSC-HM.

The work was performed by the Facility Systems Division (FS), U.S. Army Construction Engineering Research Laboratory (USACERL). The Principal Investigator was Mr. Robert Neathammer. Assistance was provided by Mr. Robert Doerr, Mr. Thomas Napier, Ms. Mary Chionis, Mr. William Dolan, Mr. John Shonder, Mr. Victor Storm, Ms. Darcy Weber, and Mr. Larry Augustine. Mr. Michael J. O'Connor is Chief of USACERL-FS. The USACERL technical editor was Gloria J. Wienke, Information Management Office.

COL Carl O. Magnell is Commander and Director of USACERL, and Dr. L. R. Shaffer is Technical Director.

CONTENTS

## TABLES



## FIGURE

# MAY 1984 TO SEPTEMBER 1988 SUMMARY OF FORT IRWIN, CA, FAMILY HOUSING COMPARISON TEST: OPERATION AND MAINTENANCE COSTS OF MANUFACTURED vs. CONVENTIONALLY BUILT UNITS

## 1 INTRODUCTION

### Background

Congress believes that use of manufactured (factory built) military housing, rather than conventionally built units, will result in lower overall costs, and provide durable housing meeting contemporary housing standards. To verify this belief, Congress directed the Department of Defense (DOD) to construct 200 units of manufactured housing at Fort Irwin, CA, and compare them with similarly designed, conventionally built housing.[1]

The manufactured units to be constructed would meet Federal Manufactured Housing Construction and Safety Standards (FMHCSS); however, upgrades in certain criteria would be specified to bring the units into conformance with DOD standards. These areas of concern include net usable floor space, energy efficiency, fire and life safety, and durability of certain materials and components. The study would compare the impact of the modified FMHCSS versus standard DOD criteria, except for the essential criteria listed above.

The study is being conducted during the first 5 years the housing units are occupied; initial occupancy on some units started in February 1983. The study compares 200 two-bedroom manufactured units to 144 two-bedroom, conventionally built units. The conditions and parameters for this test were submitted to Congress and a report of the study results will be submitted at the end of the test.

The data collected address operation and maintenance (O&M) costs and user satisfaction for both types of housing. The study identifies not only the differences, if any, in O&M costs, but also the reasons for the differences and their importance for future construction criteria, construction methods, and occupant satisfaction.

### Objective

This report's objective is to summarize the O&M costs and the occupant satisfaction data for both conventionally built and manufactured housing from construction through September 1988. This is the last in a series of interim reports; the final report on the 5-year study will be prepared in October 1989. First year data were reported in

[1] Report No. 97-44, *Military Construction Authorization Act* (House of Representatives Committee on Armed Services, 1982), pp 8-9.

USACERL Interim Report (IR) P-85/14,[2] second year data in USACERL IR P-86/06,[3] third year data in USACERL IR P-87/10[4], and fourth year data in USACERL IR P-88/09[5].

## Approach

The first step was to develop data collection and data analysis procedures. The cost comparisons and analyses for this study were established in USACERL Special Report (SR) P-140, *Fort Irwin Housing Comparison Test.*[6] The data is collected, summarized, and reported yearly.

## Scope

Costs are limited to buildings themselves; sidewalks, driveways, streets, lawns, playgrounds, and utility lines outside the buildings are not included. Also, the replacement costs of refrigerators, dishwashers, kitchen stoves, and utility meters are excluded. Costs for the first 2 years did not include the contractor's overhead and profit.

---

[2]R. D. Neathammer, *Fort Irwin, CA, Family Housing Comparison Test: Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units,* Interim Report (IR) P-85/14/ADA159740 (U.S. Army Construction Engineering Research Laboratory [USACERL], 1985).

[3]R. D. Neathammer, *Fort Irwin, CA, Family Housing Comparison Test; Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units,* IR P-86/06/ ADA175995 (USACERL, 1986).

[4]R. D. Neathammer, *Three-Year Summary of Fort Irwin, CA, Family Housing Comparison Test; Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units,* IR P-87/10/ ADA180001 (USACERL, 1987).

[5]R. D. Neathammer, *Four-Year Summary of Fort Irwin, CA, Family Housing Comparison Test; Operation and Maintenance Costs of Manufactured vs. Conventionally Built Units,* IR P-88/09/ADA190017 (USACERL, 1988).

[6]M. J. O'Connor, *Fort Irwin Housing Comparison Test,* Special Report (SR) P-140/ ADA130349 (USACERL, 1983).

## 2 REVIEW OF TEST PLAN

This section gives a short review of the test plan and the final data analyses. Data is being collected in two areas: O&M costs and occupant satisfaction.

USACERL SR P-140 detailed the cost data collection plan and analysis methods. Four basic questions on costs will be answered:

1. Are the average annual O&M costs significantly different?

2. If different, where are they significantly different?

3. Why do the costs differ?

4. What criteria, design features, etc., need to be changed as a result?

Overall maintenance costs and utility costs will be compared separately. If significant differences are found, it will be important to determine their causes.

In addition to the overall cost comparison, the maintenance costs for major building components will be compared. These comparisons will provide more detail about where and why cost differences occur.

Costs to restore each unit to a comparable level of "new plus fair wear and tear" will be determined at the end of the test period. This will be done under the guidance of the Fort Irwin DEH and the Los Angeles District Office of the Corps of Engineers.

In addition to cost comparisons, occupant satisfaction with the overall apartments and each physical part of the unit will also be compared for the two types of construction. The questions used to determine this factor are given in USACERL IR P-85/14, Appendix F. When occupant satisfaction differs for a building component, that component will be evaluated to determine the reason for the difference.

One maintenance practice may affect the test results and will be accounted for in the final evaluation. No "routine" or "preventive" maintenance was performed through 30 September 1986, although the contractor originally planned to do so. That is, no seasonal maintenance on the heating/cooling systems was done--no periodic filter changes, etc. This may impact the breakdown repairs of these systems. However, the effect should not bias the test, as both type of units were treated the same. "Preventive" maintenance is done when occupants move out; a team inspects the unit and either performs minor maintenance or writes a work order (WO) to have work done. From 30 September 1986 to 30 September 1988, Dynalectron performed scheduled maintenance (called cyclic maintenance). The workers checked all building components and performed needed repairs. The Army did renew this program in FY89.

## 3 DESCRIPTION OF THE FAMILY HOUSING UNITS

### Manufactured Housing Units (MHUs)

These 200 units consist of 50 two-story fourplexes. Each upper unit has a balcony-porch and each lower one has a patio with privacy fencing. Each unit has a refrigerator, gas range, gas water heater, garbage disposal, central air conditioning, and gas-fired forced-air furnace (all provided by the contractor). Each unit has two bedrooms, a kitchen, living-dining area, family room, one bathroom, utility room, and a one-car garage. There are two units on each level.

Initial occupancy was:

| | |
|---|---|
| 61 units | Dec 83 |
| 7 units | Jan 84 |
| 64 units | Feb 84 |
| 57 units | Apr 84 |
| 9 units | May 84 |
| 2 units | Jun 84 |

### Conventionally Built Units (CBUs)

The 144 units consist of 13 sixplexes, 6 fiveplexes, and 9 fourplexes, all two-story buildings. Each unit has two bedrooms, a kitchen, living-dining area, family room, one bathroom, utility room, either a fenced patio or balcony-porch (for upper unit), and a one-car garage. The fourplexes have two units on each level. There are two units on the second story in the five- and sixplexes with the additional unit(s) on the first level. The CBUs also have a refrigerator, gas range, gas water heater, garbage disposal, central air conditioning, and gas-fired forced-air furnace.

A detailed description of all units can be found in the Los Angeles District Office report.[7] The buildings were not specifically adapted to the desert environment but are typical Southern California design.

Initial occupancy was:

| | |
|---|---|
| 8 units | Feb 83 |
| 28 units | Mar 83 |
| 38 units | Apr 83 |
| 31 units | May 83 |
| 23 units | Jun 83 |
| 14 units | Jul 83 |
| 2 units | Aug 83 |

[7] *Fort Irwin Family Housing Study—A Report on Manufactured/Factory-Built Housing and Site-Built Housing, Fort Irwin, CA* (U.S. Army Corps of Engineers, Los Angeles District, September 1984).

## 4 DATA COLLECTION PROCEDURES

Data collected in this study and their level of detail are discussed in USACERL SR P-140. That report requires that data be collected at such a level of detail that any differences found between the two types of construction can be explained. Appendix A in IR P-85/14 lists the housing units and their identification numbers used in the data collection.

### Data Collection

Discussions were held with the technical monitor, Engineering and Housing Support Center (EHSC) representatives, the FORSCOM HQ representative, Fort Irwin personnel, and representatives of the base operations contractor, Boeing Services International (BSI), to establish the best methods of collecting the data. For O&M data, USACERL designed report forms (Appendix B of IR P-85/14). BSI was contracted to segregate all service orders for maintenance for the test units and report cost data to USACERL through the Fort Irwin Directorate of Engineering and Housing (DEH) on a monthly basis.

BSI was contracted to read gas and electric meters at the end of each month and report similarly.

Self-help data reports* and occupancy data were to be forwarded quarterly.

An occupant satisfaction questionnaire was to be given to each vacating family with a mail-back envelope to USACERL.

A new contractor, Dynalectron, became the base operations contractor effective 1 October 1986. They are performing the same services described above.

### Data Verification

USACERL is verifying the reported data several ways. Each WO document is checked against the reported data forwarded by the contractor. Discrepancies are resolved on verification visits to Fort Irwin. Additionally, the contractor has set up separate accounting codes for the two groups of units and the total billed is compared to the total obtained from summing over all the individual WO data.

USACERL developed a computer program to compare monthly readings. When apparently erroneous data occurs, the contractor is notified and corrections are made.

### Data Analysis

*Maintenance Costs*

These costs are reported on a unit-month basis and yearly basis. The data are also summarized by building component to determine if one or more components for one of

*Self-help is a program whereby occupants obtain supplies and materials from a central warehouse to make minor repairs themselves.

the types of units has large maintenance costs. If so, the reasons for these costs will be determined; i.e., what criteria or design features should be reviewed/changed?

Cost differences could be caused by material quality, installation, differences inherent to manufactured or conventional construction, and possible errors in specifications for the two projects.

Warranty work referred to the construction contractor was not included in the cost comparison since no cost data are available or applicable, as it is not a cost to the government. However, the cost of a service call to assess a problem is included.

*Energy Consumption*

Gas and electricity consumption are reported on a unit-month basis and a yearly basis. Since most of the MHUs were not completed until May 1984, prior energy consumption data for the CBUs will not be used in comparisons. (Energy consumption comparisons are only valid for the same time frame because of varying weather conditions.)

*Occupancy Effects*

Occupancy data are also being collected. These data are analyzed to ensure that both types of units have a similar distribution of occupants during the 5 years (ages, numbers). If required, these data will be correlated with O&M costs to help explain differences in costs.

*Self-Help Data*

These data are summarized to see if maintenance costs are affected.

*Occupant Satisfaction Survey*

Data from the questionnaires are analyzed to determine any differences in satisfaction with the two types of units.

## 5 WHOLE HOUSE ENERGY TESTS

Three whole-house energy tests were performed immediately upon completion of construction on a sample of units from each type of construction. Appendices C and D of IR P-85/14 give details.

### House Tightness

The number of air changes per hour were measured with the following results:

| Type | No. Units | Average Air Change Per Hour | Standard Deviation |
|---|---|---|---|
| CBU | 15 | 13.0 | 1.06 |
| MHU | 12 | 10.9 | 2.67 |

There is a statistically significant difference between the two types of construction, with the MHUs being more airtight, on the average.

### Furnace Efficiency

The furnace efficiency results were as follows:

| Type | No. Units | Average Efficiency (%) | Standard Deviation (%) |
|---|---|---|---|
| CBU | 13 | 66.2 | 6.24 |
| MHU | 16 | 79.3 | 3.36 |

The furnace efficiencies of the MHUs were significantly higher than those of the CBU.

### Wall Heat Transfer Characteristics

This parameter was not initially measured for the CBUs because of unfavorable weather during the testing period. This parameter was *calculated* for both types of construction using the designed wall construction. These data are given in Appendices C and D of IR P-85/14 and are summarized below:

| Type | No. Units | Average Heat Loss (Btu/hr-°F) | Standard Deviation (Btu/hr-°F) |
|---|---|---|---|
| CBU | 16 | 310 | 51 |
| MHU | 15 | 237 | 58 |

## 6 OPERATION AND MAINTENANCE (O&M) COSTS

### Overall Costs

The total housing unit-months and maintenance costs through September 1988 are shown below in Table 1. (Maintenance includes all types of repairs and "preventive maintenance" performed. See **Scope**, p 8, for costs excluded from the analysis.)

**Table 1**

**Total Unit/Month Costs**

| Type | No. Unit Months | Total Cost ($) | Cost/Unit/ Month ($) | Cost/Unit/ Year ($) |
|---|---|---|---|---|
| MHU | 11,020 | 314,788 | 28.57 | 343 |
| CBU | 9,439 | 250,722 | 26.56 | 320 |

Table 1 reflects all data collected through September 1988. However, the CBUs are 10 months older than the MHUs, on the average. So to get a better comparison, the costs for the *first* 4 years, 8 months for each type are shown in Table 2.

**Table 2**

**Unit/Month Costs in First 4 Years, 8 Months**

| Type | No. Unit Months | Total Cost ($) | Cost/Unit/ Month ($) | Cost/Unit/ Year ($) |
|---|---|---|---|---|
| MHU | 11,020 | 314,788 | 28.57 | 343 |
| CBU | 8,143 | 174,920 | 21.48 | 258 |

### Discussion

There was a large increase in M&R costs during FY88. This is illustrated below in Table 3.

**Table 3**

**Increase in M&R Costs**

| Date | Total MHU ($) | Cost/ Unit ($) | Total CBU ($) | Cost/ Unit($) |
|---|---|---|---|---|
| Construction - 30 September 1986 | 104,599 | 523 | 107,715 | 748 |
| 1 October 1986 - 30 September 1987 | 76,611 | 383 | 51,431 | 357 |
| 1 October 1987 - 30 September 1988 | 133,225 | 666 | 90,667 | 630 |

This is attributable to the increase in interior painting as many units were vacated for the first time or required painting on change of occupancy. See Table 4.

**Table 4**

**Painting Costs**

| Date | Total MHU ($) | Cost/ Unit ($) | Total CBU ($) | Cost/ Unit($) |
|---|---|---|---|---|
| Construction - 30 September 1986 | 5,399 | 27 | 9,453 | 66 |
| 1 October 1986 - 30 September 1987 | 13,870 | 69 | 11,988 | 83 |
| 1 October 1987 - 30 September 1988 | 54,115 | 271 | 37,920 | 263 |

Costs per unit have been increasing over time. Figure 1 shows the cost/unit/month for ages 12 to 53 months, illustrating this trend.

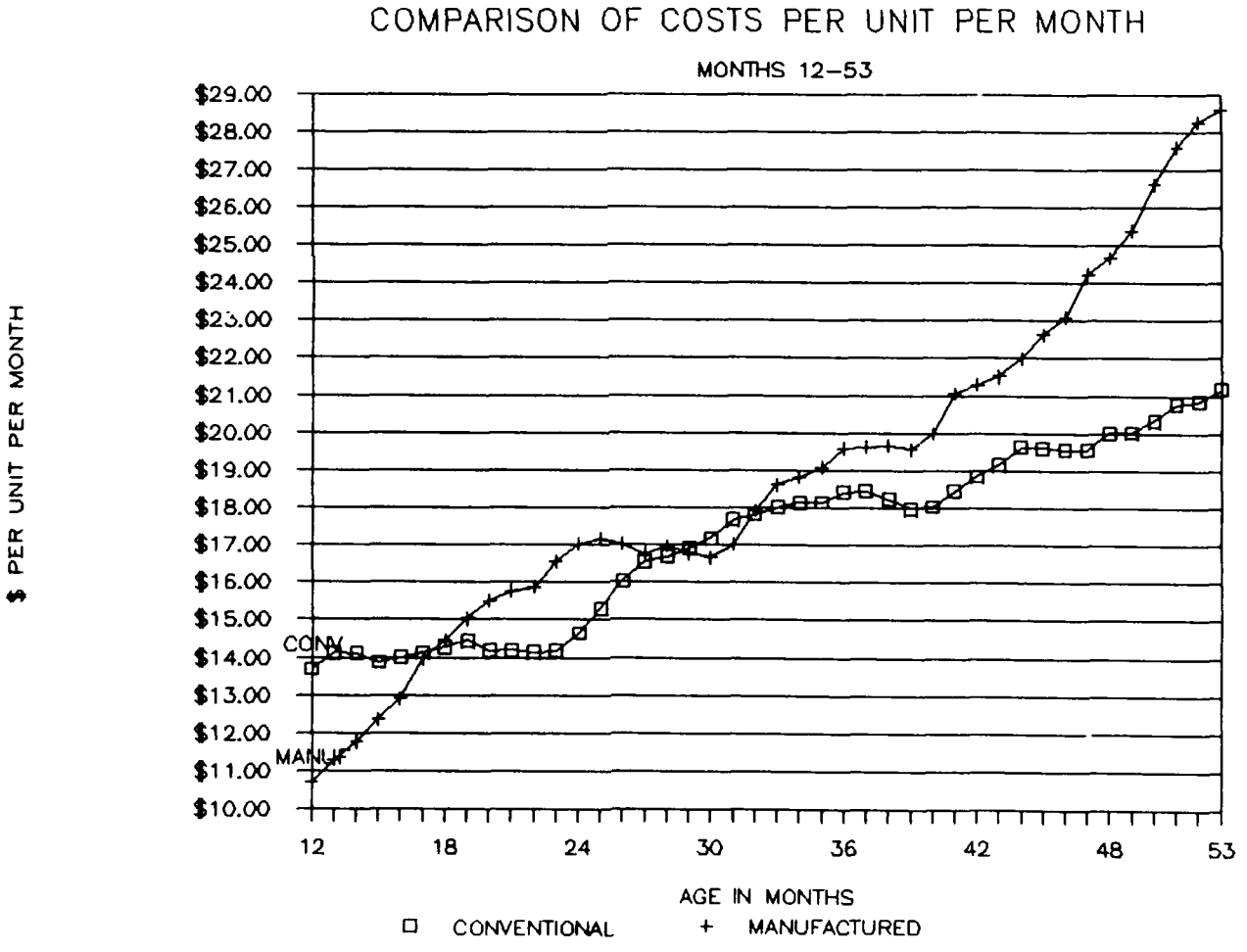


**Figure 1. Cost per unit per month over time.**

**Frequencies of Maintenance Per Housing Unit**

For the MHUs, the number of WOs for a housing unit ranges from 5 to 75. For the CBUs, the range is 10 to 77. Table 5 lists the frequencies.

**Table 5**

**Frequency of Maintenance Actions Since Units Were Occupied**

| MHU | | CBU | |
|---|---|---|---|
| No. of WOs | No. of Units With These Totals | No. of WOs | No. of Units With These Totals |
| 90+ | 8 | 90+ | 7 |
| 80-89 | 8 | 80-89 | 13 |
| 70-79 | 20 | 70-79 | 20 |
| 60-69 | 39 | 60-69 | 22 |
| 50-59 | 49 | 50-59 | 26 |
| 40-49 | 36 | 40-49 | 38 |
| 30-39 | 27 | 30-39 | 13 |
| 20-29 | 11 | 20-29 | 4 |
| 1-19 | 2 | 1-19 | 1 |

It should be noted that the "number of work orders" is the number of component actions. When a change of occupancy occurs, numerous building components are repaired--there is one official WO number but each component action is considered a WO for analysis purposes. This can be seen in Table 6.

**Table 6**

**Component Actions and Work Orders**

| | MHU | | | CBU | | |
|---|---|---|---|---|---|---|
| Date | Number Component Actions | Number WOs | Average Number WOs/Unit | Number Component Actions | Number WOs | Average Number WOs/Unit |
| Start - 30 September 1984 | 855 | 851 | 4 | 1,263 | 1,251 | 9 |
| 1 October 1984 - 30 September 1985 | 1,441 | 1,256 | 6 | 1,084 | 879 | 6 |
| 1 October 1985 - 30 September 1986 | 1,767 | 1,233 | 6 | 1,256 | 818 | 6 |
| 1 October 1986 - 30 September 1987 | 3,015 | 1,560 | 8 | 2,068 | 1,031 | 7 |
| 1 October 1987 - 30 September 1988 | 4,040 | 1,878 | 9 | 2,791 | 1,312 | 9 |
| Totals | 11,118 | 6,778 | 33 | 8,462 | 5,291 | 37 |

## Maintenance Per Component

Table 7 lists the frequencies of work orders and costs per building component, where the frequency or cost is at least 2 percent of the total number of WOs or total cost, respectively.

## Self-Help Repairs

Total self-help costs to date (not included in the overall costs shown above) are $467 for MHUs and $370 for CBUs. (The self-help program was discontinued at the end of FY85.)

**Table 7**

**Maintenance Actions Performed Per Component (Percent of WOs by Component)**

| Component No. | Description | Maintenance/Repair Actions | | Cost ($) | |
|---|---|---|---|---|---|
| | | CBU | MHU | CBU | MHU |
| | | (N=8462)* | (N=11,118) | (Total= 250,722) | (Total= 314,788) |
| 0101 | Roofing Surface | 95 (1%) | 265 (2%) | 7183 (3%) | 20097 (6%) |
| 0104 | Gutters and Downspouts | 190 (2%) | 246 (2%) | 2522 (1%) | 3100 (1%) |
| 0206 | Exterior Doors and Frames | 301 (4%) | 493 (4%) | 5698 (2%) | 10191 (3%) |
| 0207 | Storm and Screen Doors | 408 (5%) | 453 (4%) | 10970 (4%) | 14651 (5%) |
| 0209 | Storm Windows and Screens | 203 (2%) | 174 (2%) | 3688 (1%) | 2784 (1%) |
| 0214 | Interior Doors | 725 (9%) | 745 (7%) | 13891 (6%) | 10477 (3%) |
| 0217 | Kitchen Accessories, Cabinets | 131 (2%) | 170 (2%) | 1807 (1%) | 2357 (1%) |
| 0220 | Garage Door | 389 (5%) | 258 (2%) | 8068 (3%) | 4292 (1%) |
| 0301 | Resilient Flooring | ----** | 193 (2%) | ---- | 4178 (1%) |
| 0401 | Paint, Walls and Ceilings | 411 (2%) | 141 (1%) | 58342 (23%) | 70088 (22%) |
| 0607 | Heating Controls | 111 (1%) | ---- | 4368 (2%) | ---- |
| 0608 | Other Heating | 318 (4%) | 437 (4%) | 4590 (2%) | 5623 (2%) |
| 0702 | A/C Motors, Blowers, Pumps | 74 (.1%) | ---- | 5310 (2%) | ---- |
| 0704 | A/C Refrigerant | 325 (4%) | 165 (1%) | 12038 (5%) | 6296 (2%) |
| 0707 | Other Cooling | 344 (4%) | 373 (3%) | 5047 (2%) | 5495 (2%) |
| 0801 | Water Heater | 179 (2%) | 284 (3%) | 3987 (2%) | 9409 (3%) |
| 0803 | Piping, Supply | — | 252 (2%) | ---- | 8235 (3%) |
| 0804 | Faucets and Shower Heads | 323 (4%) | 728 (7%) | 7092 (3%) | 14551 (5%) |
| 0805 | Lavatories | 243 (3%) | 419 (4%) | 3670 (1%) | 9609 (3%) |
| 0806 | Water Closets | 461 (5%) | 643 (6%) | 8721 (3%) | 12143 (4%) |
| 0807 | Bathtub/Shower Unit | ---- | 209 (2%) | ---- | 4140 (1%) |
| 0904 | Wall Receptacles | 183 (2%) | 292 (3%) | 2219 (1%) | 4055 (1%) |
| 0906 | Light Fixtures | 685 (8%) | 511 (5%) | 11558 (5%) | 7648 (2%) |
| 1001 | Garbage Disposal | 215 (3%) | 351 (3%) | 4347 (2%) | 6246 (2%) |
| 1002 | Dishwasher | 201 (2%) | 490 (4%) | 7077 (3%) | 11757 (4%) |
| 1003 | Range | 471 (6%) | 707 (6%) | 11369 (5%) | 13443 (4%) |
| | Total | 6855 (81%) | 8829 (79%) | 201,753 (80%) | 258,508 (82%) |
| | Others (Less) than 2% | 1607 (19%) | 2289 (21%) | 48,969 (20%) | 56,280 (18%) |

*N = Number of WOs
**---- = Less than 2%.

## 7 ENERGY COSTS

Comparisons of gas and electricity consumption began in May 1984, since most MHUs were not occupied before then.

### Electricity Consumption

The average usage (kWh) per housing unit is shown in Table 8. For the entire 53-months data collection period, an MHU used an average total of 44,180 kWh while a CBU used an average of 40,513 kWh. This is a difference of 667 kWh ÷ 53 months = 12.6 kWh/month. At the September 1988 rate of $0.0925/kWh an MHU cost $1.17 more than a CBU for electricity per month.

### Gas Consumption

The type of gas used is liquid propane. The average monthly usage (cu ft) per housing unit is shown in Table 9.

For the 53-month period, an MHU used an average total of 81,970 cu ft while a CBU used an average total of 77,990. This is a difference of 3,980 cu ft ÷ 53 months = 75 cu ft/month. At the September 1988 cost of $0.01849/cu ft an MHU cost $1.39 more than a CBU for gas per month.

### Cost Comparison Summary

For the 4-year period (October 1984 to September 1988) the averages for dwelling unit energy consumption and cost are given in Table 10. The MHU on the average have cost $20 more per year for gas and electricity.

### Comments

The data in Chapter 5 (better air tightness and higher furnace efficiencies for the MHUs) would indicate the MHUs should use less energy than the CBUs. However, detailed energy simulations (performed at USACERL using the Building Loads Analysis and System Thermodynamics program) indicate three design/construction features negate these two measured variables: the MHUs have more window/door glass area; the MHUs have single-pane glass while the CBUs have thermal-pane; and the CBUs are built on a slab (which modulates heating/cooling demands) while the MHUs are built on a crawl space. The final report of this project will give complete details. Meanwhile, no conclusions should be drawn until the 5 year analysis is completed.

At the end of the study, energy consumptions of individual units will be compared. Any units with extremely high consumptions over several occupants will be checked to try to determine the cause.

## Table 8

### Average Monthly Electricity Consumption (kWh) Per Housing Unit

| | | 1984 May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | 1985 Jan | Feb | Mar | Apr | Monthly Avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year 1 | MHU | 780 | 1007 | 1218 | 1263 | 1001 | 557 | 445 | 486 | 484 | 427 | 423 | 633 | 727 |
| | CBU | 704 | 959 | 1170 | 1132 | 907 | 582 | 433 | 471 | 463 | 417 | 444 | 549 | 687 |

| | | 1985 May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | 1986 Jan | Feb | Mar | Apr | Monthly Avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year 2 | MHU | 679 | 1179 | 1451 | 1420 | 643 | 574 | 525 | 514 | 507 | 447 | 465 | 468 | 740 |
| | CBU | 661 | 1013 | 1425 | 1312 | 700 | 610 | 547 | 492 | 482 | 434 | 465 | 484 | 719 |

| | | 1986 May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | 1987 Jan | Feb | Mar | Apr | Monthly Avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year 3 | MHU | 828 | 1148 | 1280 | 1520 | 746 | 572 | 460 | 571 | 500 | 429 | 474 | 592 | 760 |
| | CBU | 789 | 1070 | 1270 | 1335 | 857 | 633 | 451 | 607 | 570 | 512 | 492 | 646 | 767 |

| | | 1987 May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | 1988 Jan | Feb | Mar | Apr | Monthly Avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year 4 | MHU | 665 | 1038 | 1174 | 1460 | 1035 | 679 | 503 | 520 | 476 | 487 | 464 | 470 | 743 |
| | CBU | 674 | 1060 | 1282 | 1247 | 1142 | 755 | 568 | 515 | 494 | 485 | 520 | 476 | 761 |

| | | 1988 May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|
| Year 5 | MHU | 766 | 969 | 1336 | 1438 | 1023 |
| | CBU | 771 | 885 | 1227 | 1406 | 1040 |

## Table 9

### Average Monthly Gas Consumption (cu ft) Per Housing Unit

| | | 1984 May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | 1985 Jan | Feb | Mar | Apr | Monthly Avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year 1 | MHU | 900 | 680 | 570 | 620 | 580 | 1410 | 2400 | 3560 | 3540 | 2840 | 2700 | 1460 | 1787 |
| | CBU | 710 | 640 | 530 | 590 | 530 | 1110 | 2070 | 3180 | 3220 | 2780 | 2390 | 1270 | 1591 |

| | | 1985 May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | 1986 Jan | Feb | Mar | Apr | Monthly Avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year 2 | MHU | 960 | 610 | 620 | 660 | 700 | 1050 | 2670 | 2840 | 2540 | 2260 | 1700 | 1380 | 1504 |
| | CBU | 820 | 570 | 580 | 670 | 650 | 880 | 2410 | 2560 | 2400 | 2120 | 1680 | 1360 | 1398 |

| | | 1986 May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | 1987 Jan | Feb | Mar | Apr | Monthly Avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year 3 | MHU | 910 | 560 | 600 | 610 | 840 | 1210 | 1750 | 3320 | 3390 | 2580 | 2510 | 1070 | 1623 |
| | CBU | 890 | 650 | 730 | 720 | 830 | 1110 | 1580 | 3090 | 3310 | 2670 | 2530 | 1160 | 1612 |

| | | 1987 May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | 1988 Jan | Feb | Mar | Apr | Monthly Avg |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Year 4 | MHU | 800 | 660 | 630 | 620 | 600 | 680 | 2020 | 3920 | 3320 | 2690 | 2040 | 1460 | 1621 |
| | CBU | 800 | 790 | 690 | 670 | 640 | 670 | 2080 | 3400 | 3320 | 2600 | 1980 | 1330 | 1594 |

| | | 1988 May | Jun | Jul | Aug | Sep |
|---|---|---|---|---|---|---|
| Year 5 | MHU | 124 | 68 | 56 | 64 | 66 |
| | CBU | 112 | 66 | 62 | 68 | 68 |

Table 10

Four-Year Summary of Energy Consumption

| | MHU | | CBU | |
|---|---|---|---|---|
| Unit | Gas | Electricity | Gas | Electricity |
| Average Consumption/Year Per Housing Unit | 19,701 cu ft | 8,978 kWh | 18,769 cu ft | 8,907 kWh |
| Average Cost/Year Per Housing Unit | $364 | $830 | $347 | $824 |

## 8 OCCUPANT SATISFACTION

One part of the study assesses occupants' satisfaction with their housing. The use of lower cost housing for Army personnel would not be cost effective if it created morale problems or lower reenlistment rates. A questionnaire developed at USACERL and approved by FORSCOM, EHSC, and HQUSACE is given in Appendix F of IR P-85/14.

A copy of the questionnaire with a mail-back envelope (to USACERL) is given to each vacating family by the contractor approximately 2 weeks before they leave. The family is encouraged to complete and mail it back when they vacate.

Through September 1988, 347 of 912 vacating occupants (38 percent) returned questionnaires. This response rate is considered low. Special surveys were done in September 1984, April 1985, and June 1986 of all families who had lived in their quarters at least 1 year. Of these, 122 (52 percent) returned questionnaires.

For analysis purposes, only occupants who had lived in their quarters for at least 12 months were considered, since they would have been through both heating and cooling seasons.

The responses from occupants of the two types of units were compared by performing cross tabulations. The following paragraphs show results for key questions and for questions for which occupants of the two housing types differed significantly (95 percent confidence). There were 179 responses from occupants of CBU and 190 for MHU.

Q5. How would you rate the condition of your quarters?

| | Excellent | Better than Average | Average | Below Average | Poor |
|---|---|---|---|---|---|
| CBU | 25% | 42 | 32 | 1 | 0 |
| MHU | 20 | 42 | 33 | 5 | 0 |

No statistically significant difference was found in responses between occupants of the two housing types.

Q6. In general, how satisfied have you been with these quarters?

| | Very Satisfied | Satisfied | Dissatisfied | Very Dissatisfied |
|---|---|---|---|---|
| CBU | 31% | 59 | 8 | 2 |
| MHU | 29 | 59 | 12 | 0 |

No significant difference was found.

Q7E. In general, are you satisfied with your kitchen cabinets?

| | Satisfied | Not Satisfied | No Opinion |
|---|---|---|---|
| CBU | 76% | 22 | 2 |
| MHU | 91 | 9 | 0 |

There was a difference between CBU and MHU occupants.

Q7J. In general, are you satisfied with living/dining room floors?

| | Satisfied | Not Satisfied | No Opinion |
|---|---|---|---|
| CBU First Floor | 63% | 34 | 3 |
| CBU Second Floor | 90 | 9 | 1 |
| MHU First Floor | 64 | 34 | 2 |
| MHU Second Floor | 77 | 20 | 3 |

There was a statistically significant difference between first and second floor occupants of the two housing types. Second floor units have carpet while first floor units have tile/vinyl. Second floor occupants were more satisfied.

Q7J1. How would you rate cleanability of living/dining room floors?

| | Easy to Clean | Hard to Clean | No Opinion |
|---|---|---|---|
| CBU First Floor | 58% | 36 | 6 |
| CBU Second Floor | 76 | 11 | 13 |
| MHU First Floor | 71 | 21 | 8 |
| MHU Second Floor | 57 | 25 | 18 |

There was a statistically significant difference between occupants of CBU and MHU for cleanability of living/dining room floors, caused by the CBU first floor occupants' responses.

Q7K. In general, are you satisfied with the bedroom floors?

| | Satisfied | Not Satisfied | No Opinion |
|---|---|---|---|
| CBU First Floor | 71% | 28 | 1 |
| CBU Second Floor | 97 | 0 | 3 |
| MHU First Floor | 70 | 28 | 2 |
| MHU Second Floor | 82 | 16 | 2 |

There was a statistically significant difference: second floor (carpet) occupants were more satisfied.

Q7K1. How would you rate cleanability of bedroom floors?

| | Easy to Clean | Hard to Clean | No Opinion |
|---|---|---|---|
| CBU First Floor | 65% | 31 | 4 |
| CBU Second Floor | 76 | 11 | 13 |
| MHU First Floor | 73 | 19 | 8 |
| MHU Second Floor | 66 | 16 | 18 |

There was a statistically significant difference between first floor and second floor occupants for cleanability of bedroom floors with more first floor occupants (vinyl/tile) rating it as hard to clean.

Q7M. In general, are you satisfied with the interior walls?

| | Satisfied | Not Satisfied | No Opinion |
|---|---|---|---|
| CBU First Floor | 56% | 43 | 1 |
| CBU Second Floor | 73 | 24 | 3 |
| MHU First Floor | 72 | 26 | 2 |
| MHU Second Floor | 77 | 20 | 3 |

There was a statistically significant difference: more dissatisfaction was shown by CBU first floor occupants.

Q7M1. How would you rate the cleanability of the interior walls?

| | Easy to Clean | Hard to Clean | No Opinion |
|---|---|---|---|
| CBU | 48% | 42 | 10 |
| MHU | 57 | 29 | 14 |

There was a statistically significant difference: the CBU occupants rated walls as harder to clean.

Q9-10. There was no difference between CBU and MHU for noise/odor annoyance from other quarters.

Q15. Please list three things about your apartment you like most.

Of 828 items listed:

| | | | |
|---|---|---|---|
| Dishwasher | - 10% | Separate laundry room | - 10% |
| Garage | - 9% | Kitchen arrangement | - 6% |
| Air Conditioner | - 8% | Design | - 5% |
| Roominess | - 8% | | |

Q16. Please list three things about your apartment you do not like.

Of 609 items listed the following were listed most frequently:

| | | | |
|---|---|---|---|
| Floors | - 10% | Bathroom too small | - 4% |
| Neighbors' noise | - 6% | Cheap construction | - 3% |
| Thin walls | - 5% | Cheap carpeting | - 3% |
| Sprinklers | - 4% | | |

Q17. Please make any general comments about your apartment:

Of 159 comments these occurred frequently:

| | | |
|---|---|---|
| Satisfied with apartment | - | 35% |
| Very satisfied with apartment | - | 30% |
| Cheap construction | - | 14% |

## 9 RESULTS TO DATE

This interim report has summarized the O&M costs and occupant satisfaction data collected for conventionally built and manufactured housing units at Fort Irwin, CA. The data cover a 5-year period from construction through September 1988. Through the first 4 years, 8 months of occupancy there is a 33 percent ($85) difference per unit in yearly maintenance and repair costs between the two types of units (MHU have higher costs). For 4 years energy costs the MHU are higher than for the CBU (about $23/year per unit); and occupants of the two types of units are equally satisfied with their apartments.

Through September 1988 the occupancy rates for the two groups are very similar: CBU, 98.0 percent; and MHU, 97.8 percent.

# USACERL Distribution

Chief of Engineers
ATTN: CEIM-SL (2)
ATTN: CECC-P
ATTN: CECW
ATTN: CECW-O
ATTN: CECW-P
ATTN: CECW-RR
ATTN: CEEC
ATTN: CEEC-C
ATTN: CEEC-E
ATTN: CERD-L
ATTN: CERD-C
ATTN: CERD-M
ATTN: CERM
ATTN: DAEN-ZCE
ATTN: DAEN-ZCI
ATTN: DAEN-ZCM
ATTN: DAEN-ZCZ

USAEHSC ATTN: CEHSC-EB 22060
ATTN: CEHSC-F
ATTN: CEHSC-HM
ATTN: Canadian Liaison Officer
ATTN: Engr Studies Center

US Army Engineer Districts
ATTN: Library (41)

US Army Engineer Divisions
ATTN: Library (14)
ATTN: CESPL-CO-C (2)

US Army Europe
ODCS/Engineer (2) 09403
V Corps
ATTN: DEH (11)
VII Corps
ATTN: DEH (16)
21st Support Command
ATTN: DEH (12)

8th USA, Korea
ATTN: Facilities Engineer

USA Japan (USARJ)
ATTN: AJEN-FE 96343

US Military Academy 10996
ATTN: Facilities Engineer

AMC - Dir., Inst., & Svcs
ATTN: DEH (23)

FORSCOM
FORSCOM Engineer, ATTN: FCEN-RDM
ATTN: Facilities Engineer (27)

HSC
Ft. Sam Houston AMC 78234
ATTN: HSLO-F
Fitzsimons AMC 80045
ATTN: HSHG-DEH
Walter Reed AMC 20307
ATTN: Facilities Engineer

INSCOM - Ch, Instl. Div
Arlington Hall Station (4) 22212
ATTN: Facilities Engineer

Military Dist of Washington (MDW)
ATTN: DEH
Cameron Station (3) 22314
Fort Lesley J. McNair 20319
Fort Myer 22211

Military Traffic Mgmt Cmd (MTMC)
Falls Church 20315
Oakland Army Base 94626
Bayone 07002
Sunny Point MOT 28461

TRADOC
HQ, TRADOC, ATTN: ATEN-DEH 23651
ATTN: DEH (18)

USAIS
Fort Huachuca 85613
ATTN: Facilities Engineer (3)
Fort Ritchie 21719

WESTCOM
Fort Shafter 96858
ATTN: DEH

Commander
National Training Center
ATTN: AFZJ-EHO (2)

U.S. Army Corps of Engineers
ATTN: CESPL-CO-HI (2)

U.S. Army Europe
ATTN: C/AEAEN-EH-H

CECRL, ATTN: Library 03755

WES, ATTN: Library 39180

Tyndall AFB, IL 32403
AFESC/Engineering & Service Lab

NAVFAC
ATTN: Naval Public Works Ctr (9)
ATTN: Naval Civil Engr Lab (2)

NCEL 93043
ATTN: Library (Code L08A)

Engineering Societies Library
New York, NY 10017

US Government Printing Office 22304
Receiving/Depository Section (2)

National Bureau of Standards 20899

Defense Technical Info. Center 22314
ATTN: DDA (2)